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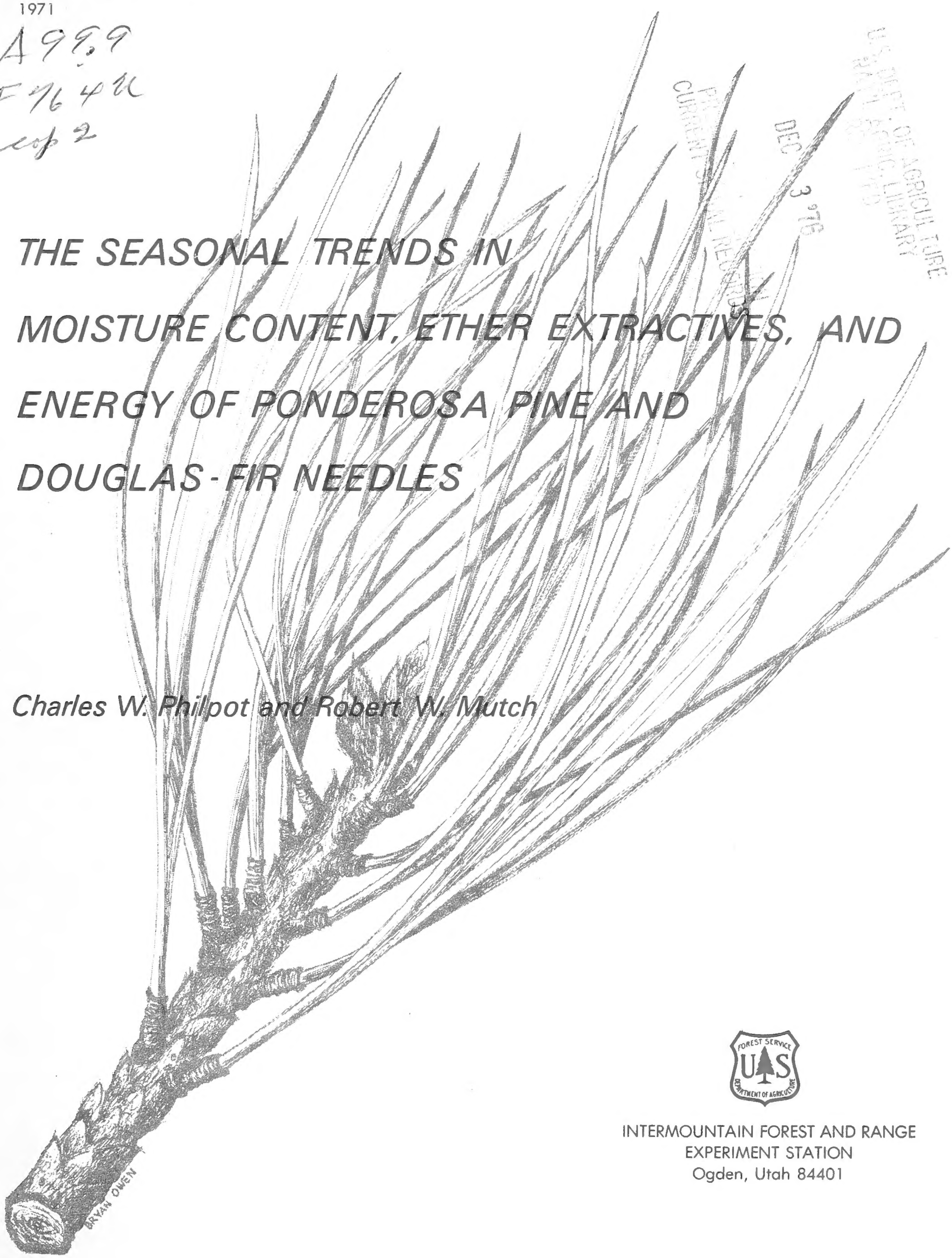
THE SEASONAL TRENDS IN MOISTURE CONTENT, ETHER EXTRACTIVES, AND ENERGY OF PONDEROSA PINE AND DOUGLAS-FIR NEEDLES

Charles W. Philpot and Robert W. Mutch



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ABSTRACT

The moisture, ether extractive, and energy content of ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* L.) foliage were measured during two fire seasons. The moisture content of 1- and 2-year-old needles was found to rise throughout the summer. The ether extractive content was highest in the fir foliage at the end of summer when fire severity is generally thought to be highest. Pine foliage extractive content was high throughout the sample period. The energy content of the extracted leaves and the extractives varied through the summer. There may be a relationship between the extractives and crown fire potential in these species.

INTRODUCTION

Why does fire behavior show a seasonal change? Generally speaking, this occurs because of changes in the fire environment. Moisture content traditionally has been cited as the important change in fuel that conditions flammability and fire behavior (Hawley 1926; Davis 1959). The moisture contained in fuels is important because it acts as an energy sink, diluting the volatiles, and excluding oxygen from the combustion zone. There are many studies on moisture content of living plants,[1] but only a few apply to this paper that discusses moisture, ether extractives, and energy of conifer crowns.

In the late 1930's Connaughton and Maki[2] found that moisture content of ponderosa pine foliage varied inversely with soil moisture and climatic drying during the fire season in northern Idaho. The fact that moisture content increases in ponderosa pine foliage during June, July, and most of August is interesting since crown fires are more prevalent as the fire season progresses in this region.

Philpot found the same general situation in ponderosa pine in the central Sierra Nevada of California with moisture increasing through most of the fire season and then leveling off.[3] A similar trend was also found for pinyon pine and juniper in Arizona and Utah (Jameson 1966), and for five coniferous species in eastern Canada (Van Wagner 1967). After finding high moisture contents in conifers in the Lake States during periods of high crown fire potential, Johnson (1966) concluded, "In our search for a satisfactory explanation for crown fires, we must apparently look beyond needle moisture content."

Can our concept of fire environment go beyond the commonly accepted fire climate-fuel moisture basis of fire occurrence? Dry seasons and moisture content regimes certainly determine the actual fire seasons, but recent studies suggest that inherent plant chemistry and chemical changes contribute materially toward the availability of energy to the combustion process (Philpot 1968, 1969a). Plant communities which have survived fires for tens of thousands of years may not only have selected survival mechanisms, but also inherent flammable properties that provide a competitive advantage and contribute to perpetuation of fire-dependent communities (Mutch 1970). This broader concept of fire environment encompasses not only moisture relations, but inherent energy and physical properties as well.

Since living foliage contributes significantly to the energy field of many large fires, the objective of this study was to determine simultaneous trends of moisture contents, ether extractives, and heat contents for Douglas-fir *(Pseudotsuga menziesii* L.) and ponderosa pine *(Pinus ponderosa* Laws.) foliage during the 1968 and 1969 fire seasons. These three variables should be studied together to arrive at meaningful conclusions about their relative importance to seasonal fire behavior.

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[1] C. W. Philpot. Vegetation moisture trends in the central Sierra Nevada. (Unpublished master's thesis on file at School of Forestry, Univ. of Calif., Berkeley) 53 p., 1963.

[2] C. A. Connaughton and T. E. Maki. The volatility content (particularly moisture) of evergreen foliage during periods of drought stress. (Unpublished office report USDA Forest Serv. on file at Intermountain Forest and Range Exp. Sta., Northern Forest Fire Lab., Missoula, Mont.) 1935.

[3] Philpot, op. cit.

An understanding of the energy levels is essential to the quantitative study of combustion in wildland fuels and the definition of such fundamental variables as fuel energy, fire intensity, combustion rate, and heat yield. Byram (Davis 1959) emphasized this point by stating that, "The energy which maintains the chain reaction of combustion is the heat of combustion--a quantity which can be measured for any particular fuel."

Heat content values have been reported for a wide variety of wood fuels, but energy studies of lesser vegetation have probably received most attention from ecologists interested in the application of caloric values to the energy relationships of ecosystems (Long 1934; Golley 1961; Bliss 1962). Golley (1961) concluded that prior to making intensive measurements of energy flow the heat contents must be determined under the specific conditions of a particular study because of variability of plant material. His examination of more than 600 records of plants indicated that significant differences in heat content exist between plant parts, between vegetation collected in different months, and between vegetation growing in different ecological communities. Bliss (1962) found that heat content values for the anatomical parts of evergreen shrubs exceeded those for deciduous shrubs in nearly all cases; however, a significant difference was not established. Amiot (1959) found that the heat of combustion of litter samples differed considerably by forest type; the more coniferous trees the stand contained, the higher was the heat of combustion of its litter. Variations in heat content by needle age, elevation, and season of year were determined for five coniferous species at the Priest River Experimental Forest in Idaho during 1962 and 1963 prior to this current study[4] (table 1). Hough (1969) recently determined the energy values of some forest fuels from the southern United States.

Table 1.--*Heat content (B.t.u./lb.) of coniferous needles, stratified by needle age and elevation, collected at Priest River Experimental Forest in Idaho, November 1962 and June 1963*

Species	November 1963		June 1963	
Ponderosa pine	2,300 ft.	2,620 ft.	2,300 ft.	2,620 ft.
	- - - - - -	- - - - - *B.t.u./lb.*	- - - - - -	- - - - - -
New	8,268±3	8,691±8	8,419±51	8,486±12
1 year	8,698±12	8,735±4	8,706±28	8,885±10
2 year	[1]--	8,639±22	8 672±83	8,862±28
3 year	--	--	--	8,806±16
Dead ground	8,747±21	8,866±23	8,677±11	8,627±15
Western white pine	2,240 ft.	2,500 ft.	2,240 ft.	2,500 ft.
New	8,687±9	8,676±11	8,325±10	8,402±22
1 year	8,799±4	8,675±23	8,743±19	8,553±33
2 year	--	8,752±15	8,803±20	8,568±41
3 year	--	--	--	8,593±17
Dead ground and/or tree	8,752±15	8,678±15	8,540±14.2	8,446±19
Lodgepole pine	2,300 ft.	5,040 ft.	2,300 ft.	5,040 ft.
New	8,709±11	8,853±5	8,486±4	8,544±10
1 year	--	8,972±28	8,712±8	8,927±18
2 year	8,962±11	9,057±12	8,799±14	8,963±34
3 year	--	9,113±18	8,846±18	9,037±34
4 year	--	9,186±27	--	9,083±10
Dead ground	8,861±9	--	--	--
Grand fir	2,240 ft.	3,900 ft.	2,240 ft.	3,900 ft.
Current	8,594±11	8,793±16	8,612±11	8,510±28
Western larch	2,300 ft.	3,900 ft.	2,240 ft.	3,900 ft.
Current	8,018±27	8,082±27	7,961±7	7,904±9

[1]Dash indicates no needles collected in that age group.

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[4]R. W. Mutch. Caloric content in coniferous needles. (Unpublished office report USDA Forest Serv., on file at Intermountain Forest and Range Exp. Sta., Northern Forest Fire Lab., Missoula, Mont.). 1963.

Table 2.--*Lower limits of flammability of gases in air*[1]

Gases	Percent gas to air
Methane	5.00
Propane	2.12
Butane	1.86
Ethanol	3.28
Diethyl ether	1.85
Hydrogen	4.00
Ethylene	2.75
Acetylene	2.50
Octane	.95
Turpentine[2]	.80

[1]Handbook physics and chemistry, 38th Ed., p. 1788, 1956-57. Chemical Rubber Publishing Co.
[2]$\alpha + \beta$ pinene

The ether extractives (crude fat content) are composed of many compounds, including oils, waxes, fats, and terpenes. Crude fat content is directly related to the total energy content of plants (Bliss 1962; Philpot 1969b). These extractives could be important for several reasons: first, they have a very high energy content, up to 23,000 B.t.u./lb.;second, a portion of them is more available to combustion than the other major components of the fuel because of their high vapor pressure and, in some cases, because of their location on fuel surfaces (Philpot 1969b). Also, terpenes have one of the lowest fuel/air ratios of any organic fuel (table 2). They vary seasonally in many fuels, reaching a maximum at the height of the fire season (Philpot 1969b; Richards 1940). For example, consider the trend in ether extractives in aspen leaves during the 1968 fire season in western Montana (fig. 1). The energy increase in fuels during the fire season is due mainly to extractive accumulation or changes in extractive composition.

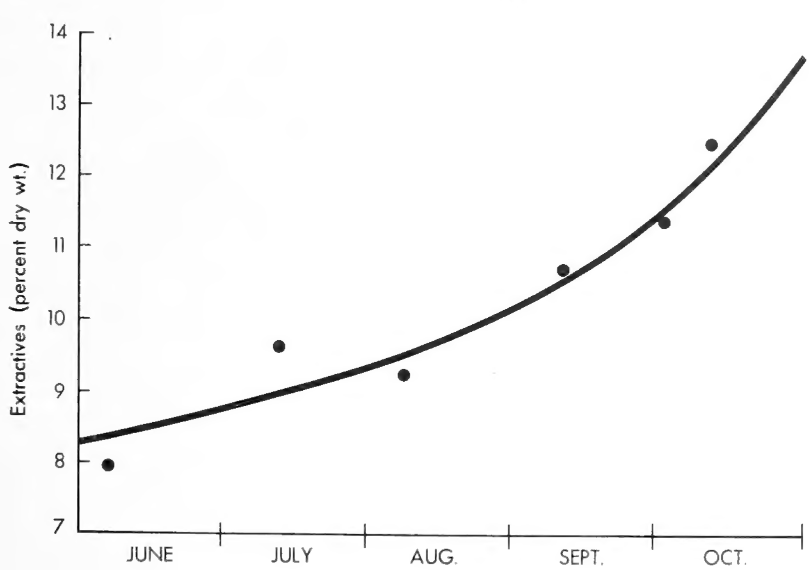

Figure 1.--The trend of ether extractive content in aspen during the fire season in western Montana.

METHODS

Two sites in western Montana with mixed ponderosa pine and Douglas-fir, approximately 1 acre each, were used for this study. In 1968 the moisture content, ether extractive, and energy data were collected from a stand at 3,500 feet, southwest exposure, and 58-percent slope. The ponderosa pine averaged 24 feet high and 4.9 inches d.b.h. The Douglas-fir averaged 31 feet high and 5.2 inches d.b.h. Physiological changes that might result from the large amount of foliage sampling required in this study necessitated a change of site in 1969. The 1969 site was at 3,840 feet, southwest exposure, and less than 10-percent slope. On this site, the pine averaged 39 feet high and 10.9 inches d.b.h., and Douglas-fir averaged 38 feet high and 8.5 inches d.b.h. All trees were dominant or codominant.

Twelve trees of each species were randomly tagged on each site. Three trees of each species were randomly chosen for sampling on a given date. All sampling occurred between 1300 and 1600 hours to minimize the effect of diurnal variation.[5] Two branches from each tree were cut from the middle one-third of the south side of the crown. A portion of the needles of each age class (new, 1 year, and 2 years) was immediately sealed in a tared 500 ml. flask. These flasks were placed in an insulated container in the field and the same flasks were used for moisture determination by solvent distillation (fig. 2). The foliage for extractive and energy determinations was placed in an insulated chest and frozen with dry ice. The frozen samples were separated by age class and placed on a freeze dryer for 14 hours. They were then ground in a Wiley mill and sifted to 40-60 mesh. Ether extractives (AOAC 1965) and heat content (ASTM 1967) were determined by standard methods. Energy content of untreated and ether extracted 1-year-old foliage samples was determined. All extractive and energy data were reduced to a dry weight basis by Karl Fischer titration (ASTM 1962).

Precipitation, temperature, and humidity were measured at a nearby fire-weather station and the buildup index was computed (USDA Forest Service 1964). The moisture and extractive content data were statistically analyzed using Tukey's test (Snedecor 1956).

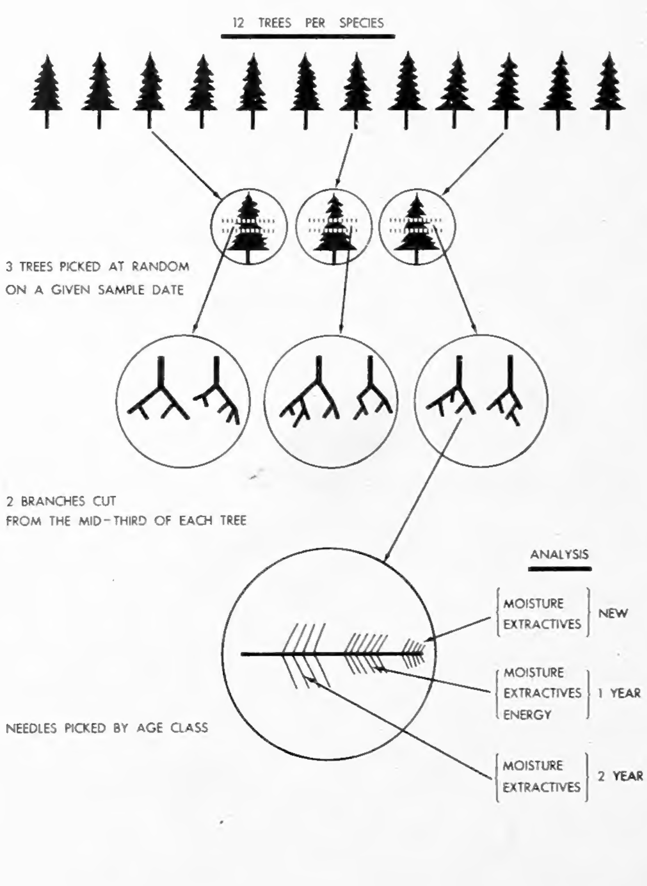

Figure 2.--The foliage sampling scheme used for ponderosa pine and Douglas-fir

[5]Philpot, op. cit.

RESULTS
Weather Factors

The two "fire seasons" differed quite drastically in terms of temperature, humidity, and precipitation trends. Perhaps the most striking difference was in quantity and distribution of precipitation (fig. 3). The main difference between humidity patterns for 1968 and 1969 occurred after August 1. During 1968, the average humidities at 1630 hours were around 40 percent or higher throughout August and September. However, during 1969 humidities averaged 20 percent and did not rise above 30 percent until mid-September. Temperatures during the same period averaged about 20° higher in 1969.

The National Fire-Danger Rating Buildup Index, which accumulates daily drying conditions by integrating temperature, humidity, and rainfall, was plotted for 1968 and 1969 (fig. 4). On August 12 of both years the index had reached 200 or above. The index dropped to below 25 on August 13, 1968, and remained below 50 for the rest of the summer. In 1969 the index kept climbing until it reached 380 on September 18, at which time it dropped due to the first fall rains. These weather data show that the months of August and most of September were wet and cool in 1968 and dry and hot in 1969.

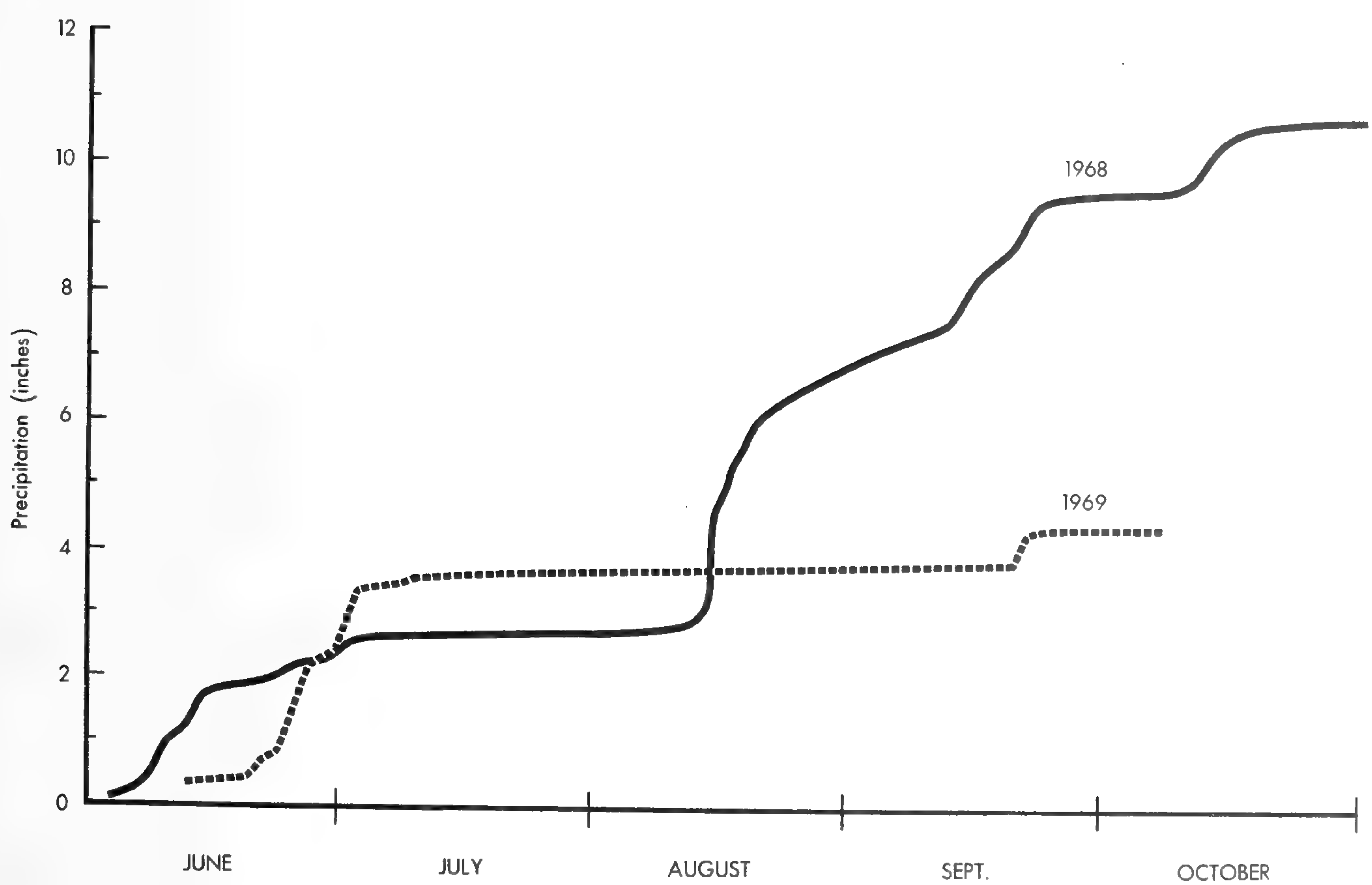

Figure 3.--The accumulated precipitation during the 1968 and 1969 fire seasons.

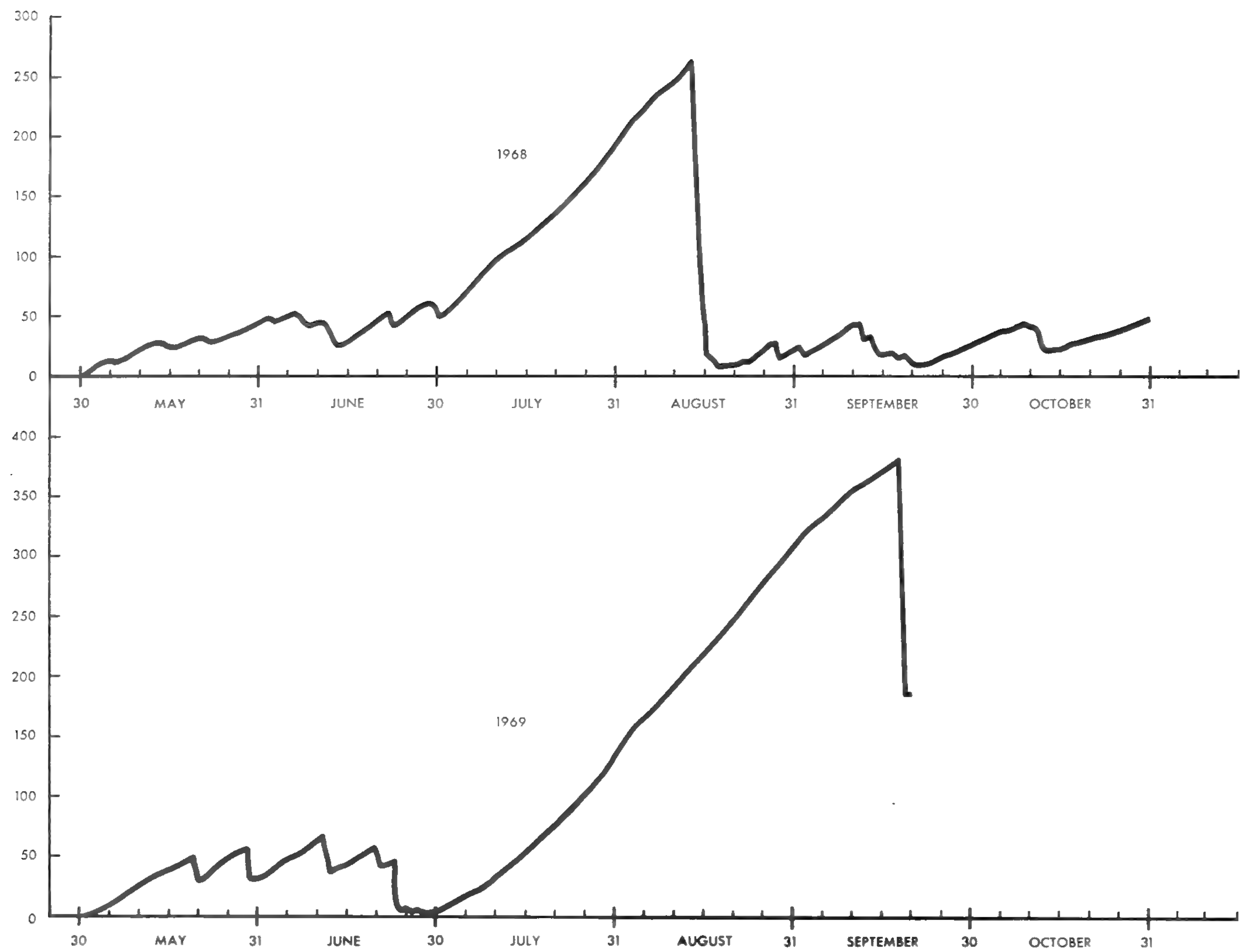

Figure 4.--The buildup index for 1968 and 1969.

Needle Moisture

The percent moisture content of new pine and fir needles fell from above 200 percent (dry weight) in June to about 130 percent by mid-August for 1968 and 1969, although there is an apparent difference in trends between years (figs. 5, 6, 7, and 8). However, the mature pine and fir needles began the fire season well below 100 percent. In fact, Douglas-fir needles (1 and 2 year) were below 80 percent in June 1968. All mature needles appeared to gain moisture during the fire season, reaching levels of 110 to 120 percent. Very little if any gain occurred past mid-August.

The moisture content trends for 2-year-old pine and fir needles collected during the 1968 fire season were statistically significant. The same is true for: 1-year-old pine, 1968; 2-year-old pine, 1969; and 1-year-old fir, 1969 (Appendixes A, B, C, and D). Also, the trends for all new needles were statistically significant.

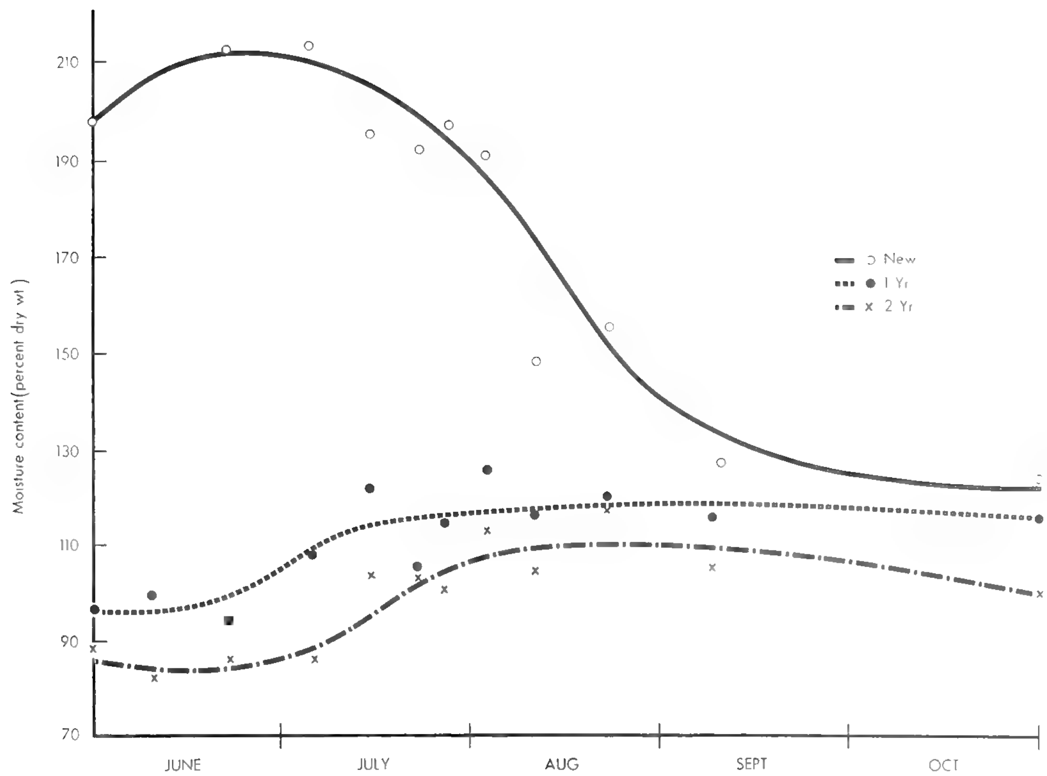

Figure 5.--The moisture content of ponderosa pine needles during the 1968 fire season.

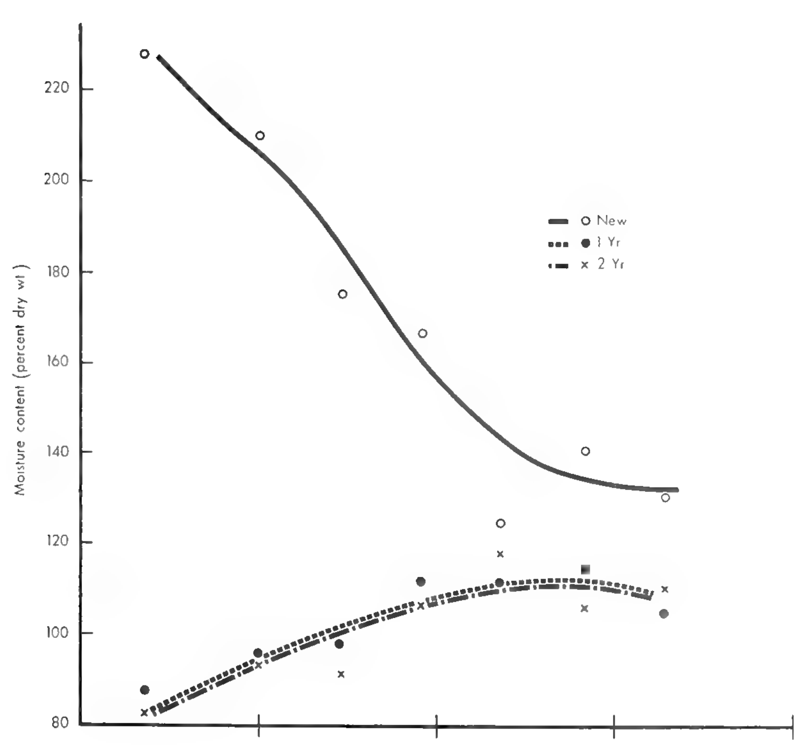

Figure 6.--The moisture content of ponderosa pine needles during the 1969 fire season.

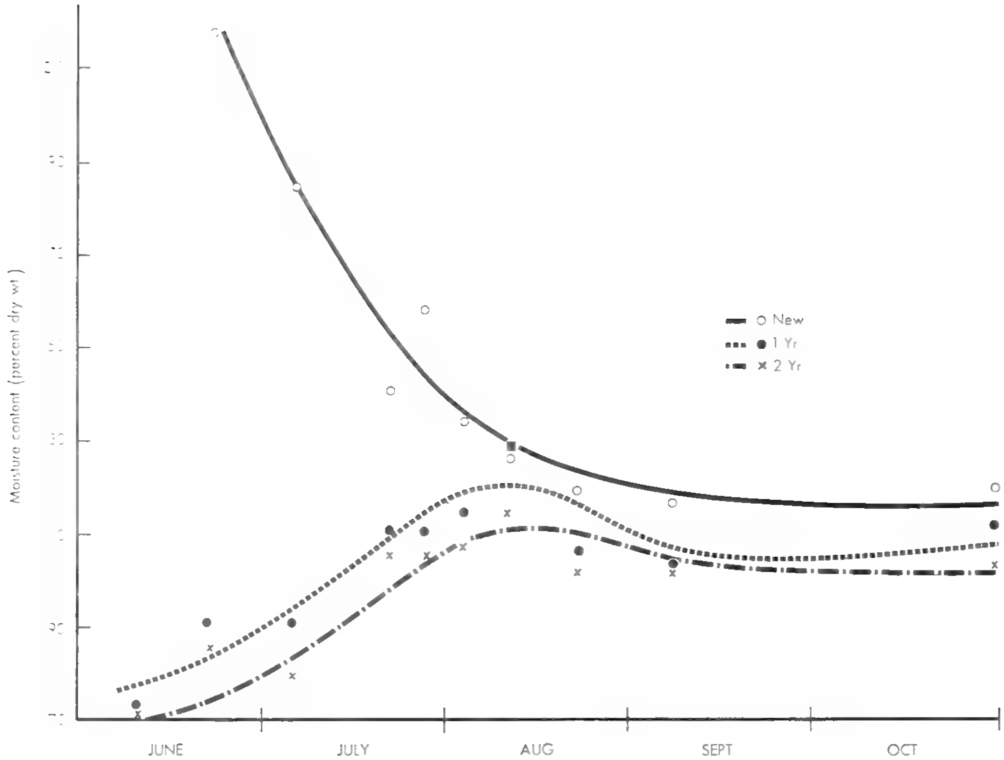

Figure 7.--The moisture content of Douglas-fir needles during the 1968 fire season.

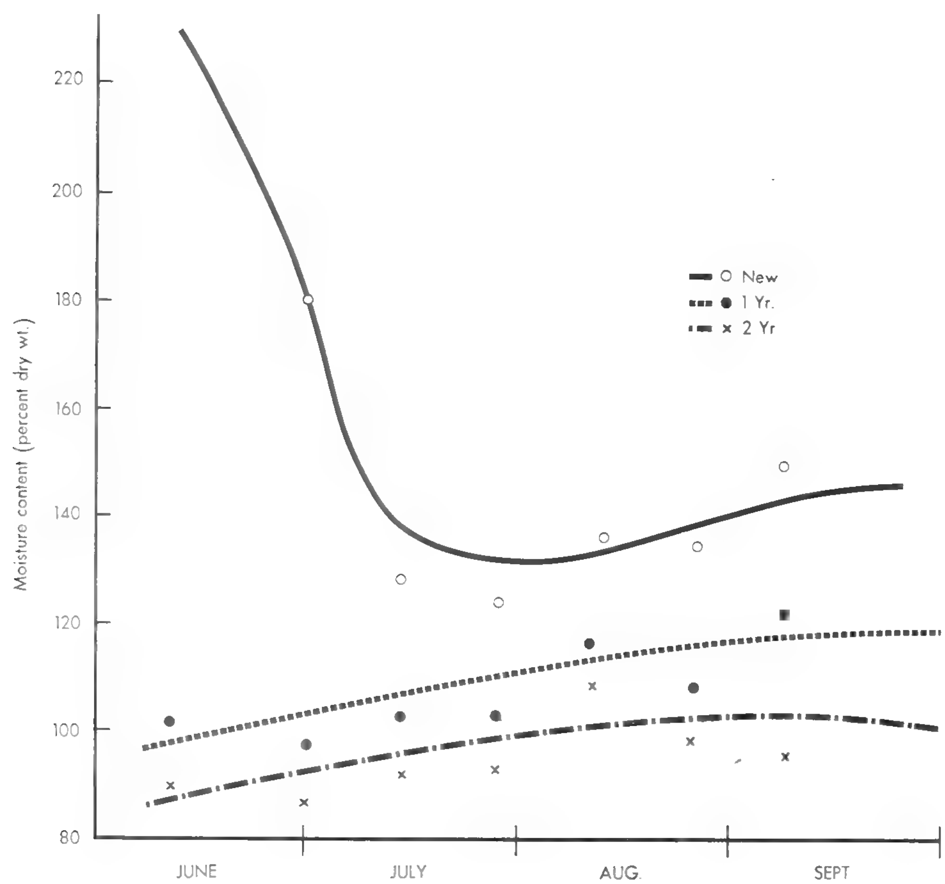

Figure 8.--The moisture content of Douglas-fir needles during the 1969 fire season.

Extractives

During both summers, Douglas-fir needles showed much more change in extractive content than did ponderosa pine. In 1968 fir needles gained in extractives until mid-August, at which time they decreased (fig. 9). This trend was statistically significant at the .05 level (fig. 10) (Appendix E). Pine showed a similar trend of lower magnitude in 1968, but it was not significant (Appendix F). Pine showed little or no change during 1969, but fir had a significant increase from 4-1/2 to 8 percent during the 1969 fire season (figs. 11 and 12) (Appendixes G and H).

An interesting aspect of these trends is the difference between 1968 and 1969. The mid-summer decrease in 1968 coincided with the onset of precipitation, while during the dry year the gain in extractives continued through to September. Pine seemed to maintain a high extractive content (8-9 percent) during both fire seasons, but a dip did occur in 1968 in early August. Tukey's test (1956) showed this dip to be statistically insignificant.

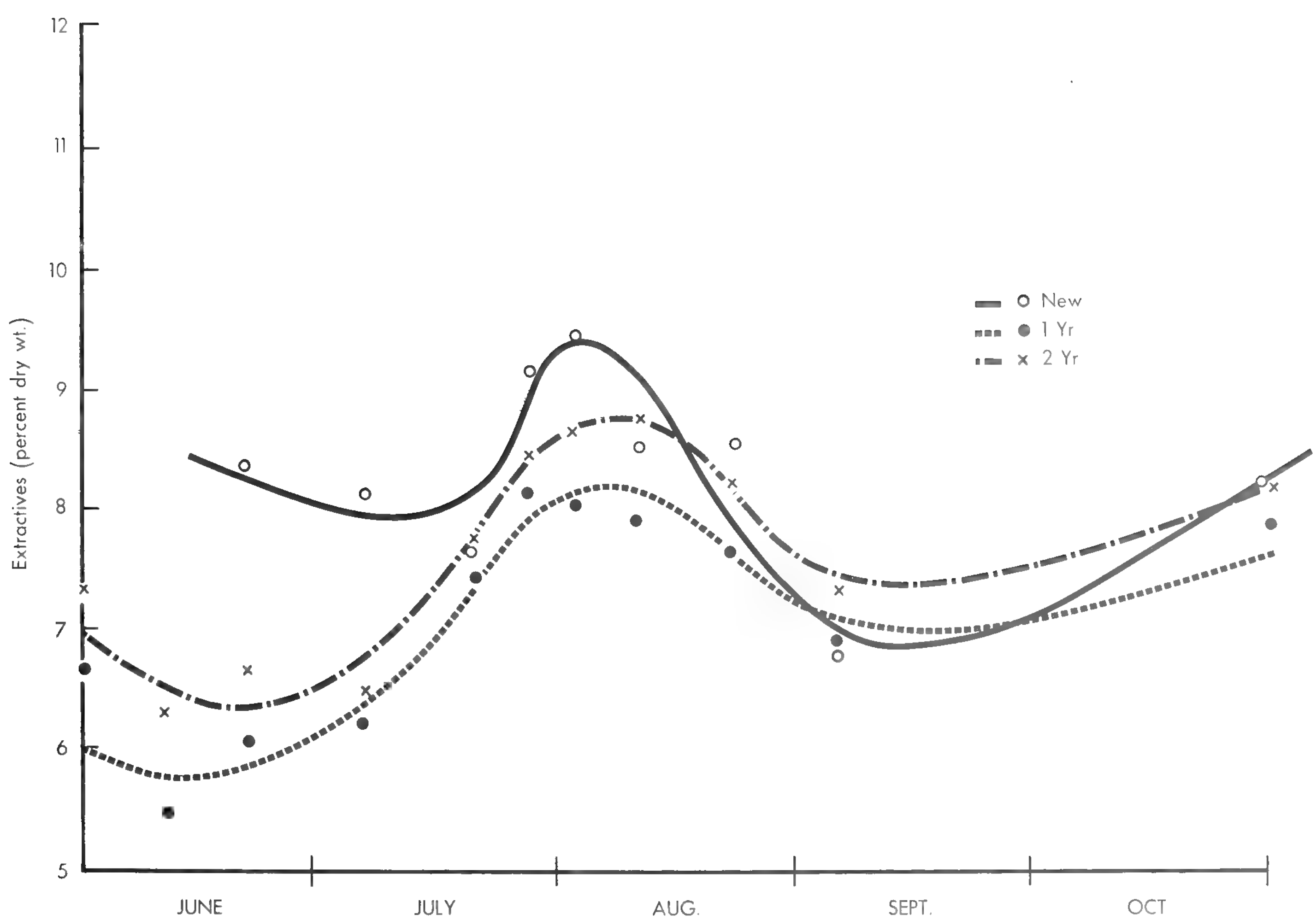

Figure 9.--The ether extractive content of Douglas-fir needles during the 1968 fire season.

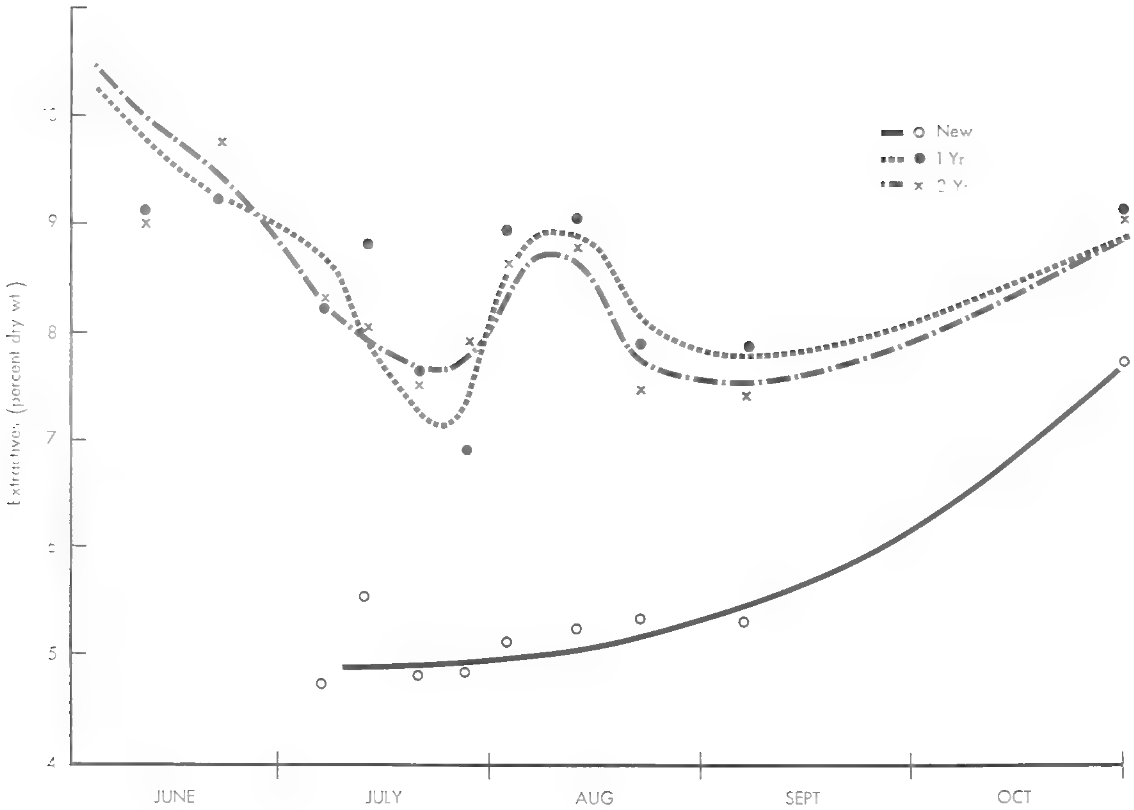

Figure 10.--The ether extractive content of ponderosa pine needles during the 1968 fire season.

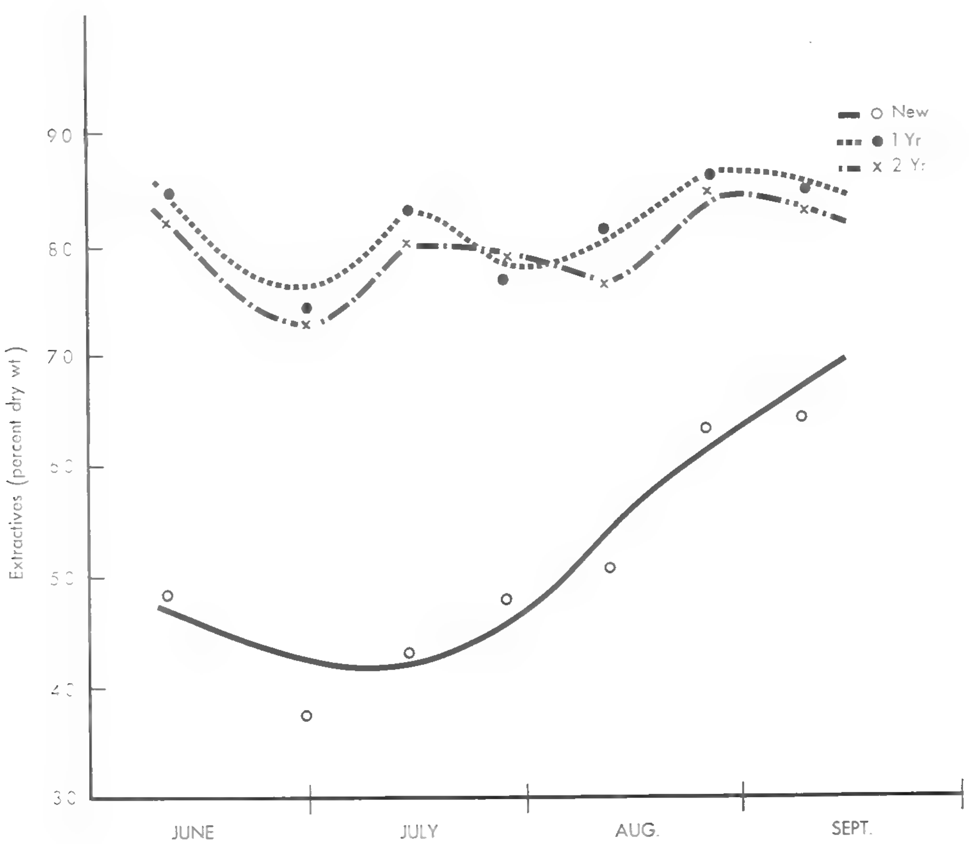

Figure 11.--The ether extractive content of ponderosa pine needles during the 1969 fire season.

PHILPOT, CHARLES W., and MUTCH, ROBERT W.

1971. The seasonal trends in moisture content, ether extractives, and energy of ponderosa pine and Douglas-fir needles, USDA Forest Serv. Res. Pap. INT-102, 21 p., illus.

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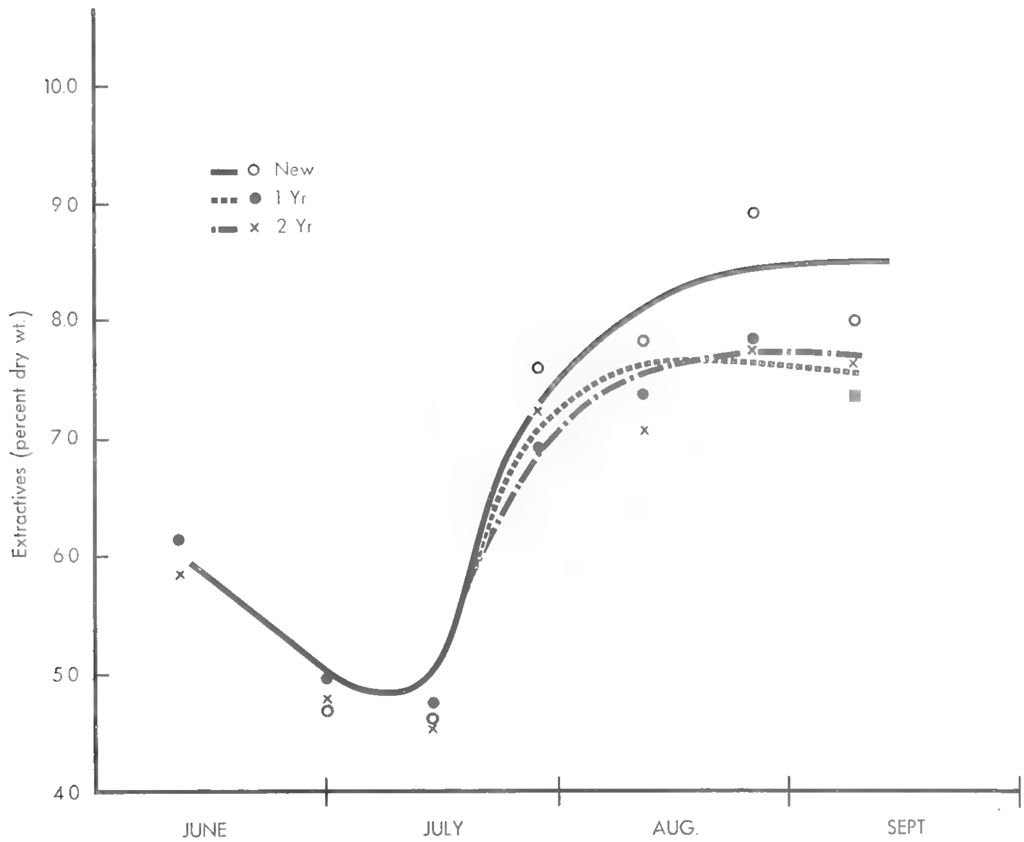

Figure 12.--The ether extractive content of Douglas-fir needles during the 1969 fire season.

Energy Content

The energy content of fir needles showed the most increase during the fire season, amounting to about 700 B.t.u./lb. in 1968 and 500 B.t.u./lb. in 1969 (figs. 13 and 14). Pine gained 400 and 200 B.t.u./lb. respectively (figs. 15 and 16). Pine showed a decrease during both years up to August and then an increase; fir generally gained during the summer. Most of this gain in fir was due to an increase in extractive content in 1969, while no similar trend occurred in 1968. (H_{diff} = difference between total energy content, H_{tot}, and energy content of the extracted needles, H_{ext}.) The extractives from Douglas-fir and ponderosa pine average about 16,000 B.t.u./lb. with a range of 14,000 to 20,000 B.t.u./lb. The increase in energy content of the fir in 1968 was due mainly to the energy change in the extracted needles. These data were not subjected to statistical analysis because the extensive time involved in calorimeter runs resulted in a limited amount of data. Generally speaking, these data show that fir gains in energy during the fire season, while pine decreases from May to August and then gains again. The change in fir is due to the change in extractive content and energy content of the extracted needles. The change in pine is apparently caused by a change in energy content of the extractives themselves, which implies a compositional change.

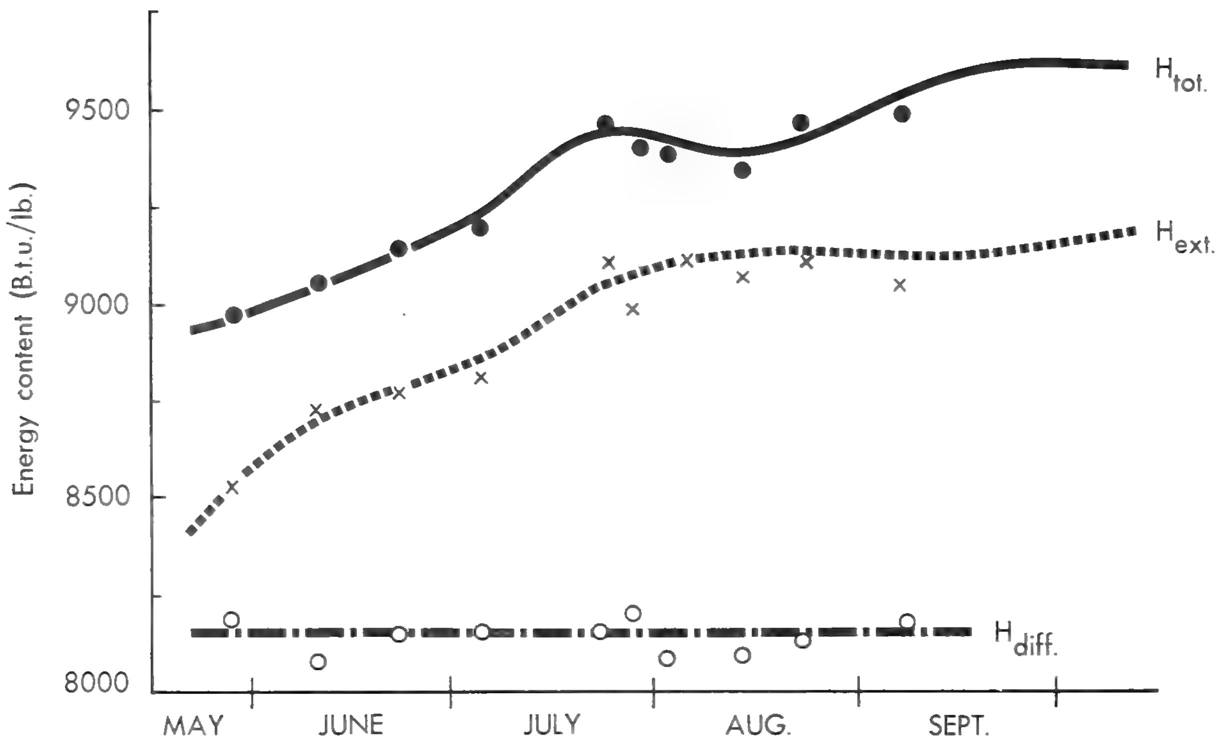

Figure 13.--The energy content of Douglas-fir needles, extracted needles, and H_{diff} during the 1968 fire season.

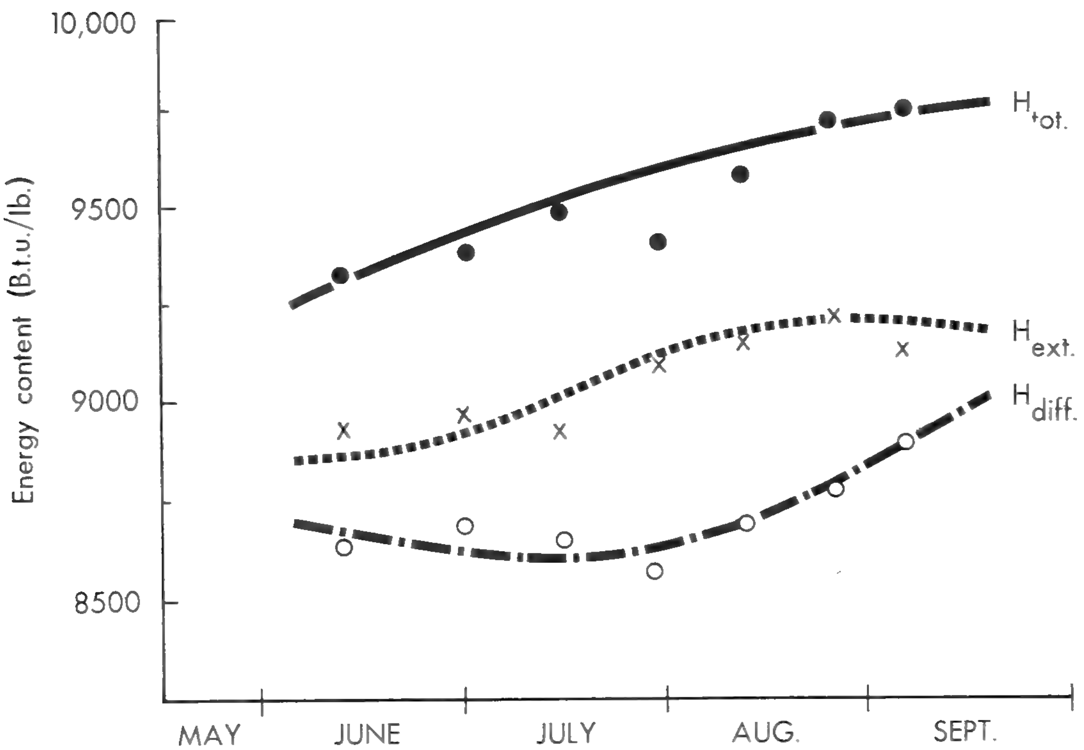

Figure 14.--The energy content of Douglas-fir needles, extracted needles, and H_{diff} during the 1969 fire season.

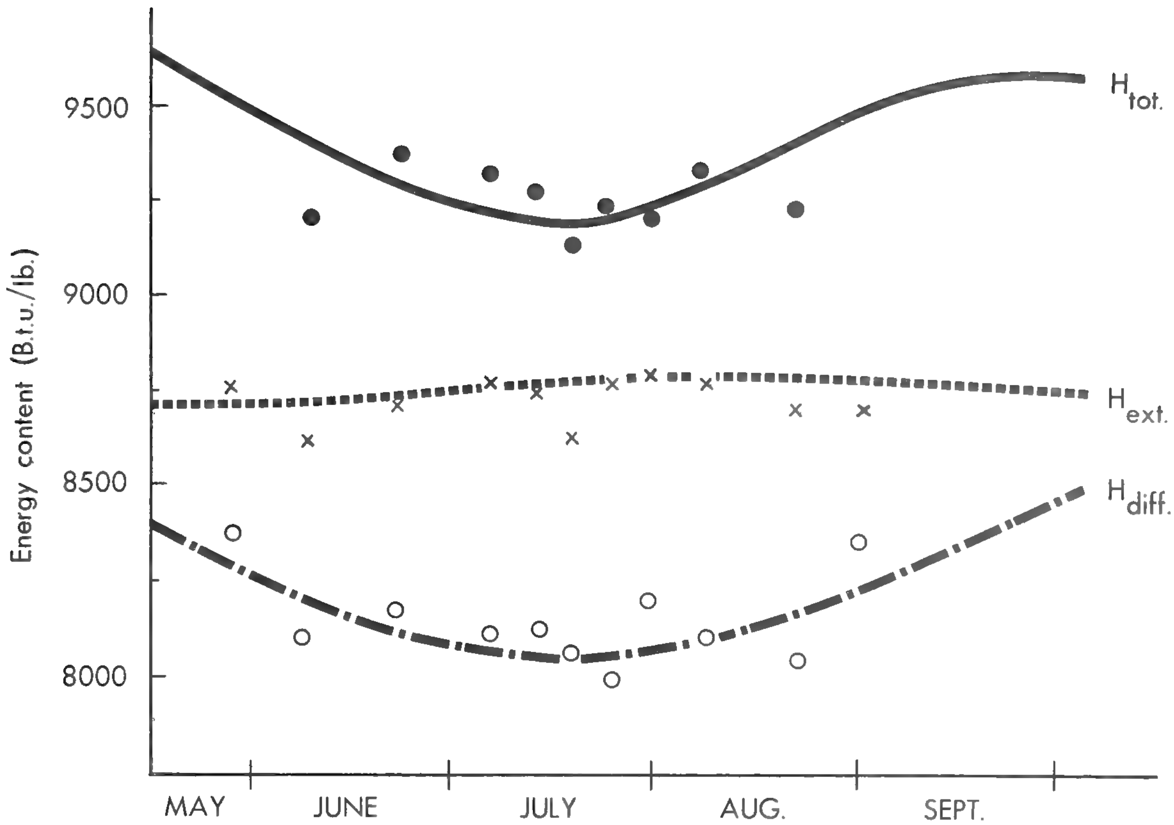

Figure 15.--The energy content of ponderosa pine needles, ether extracted needles, and H_{diff} during the 1968 fire season.

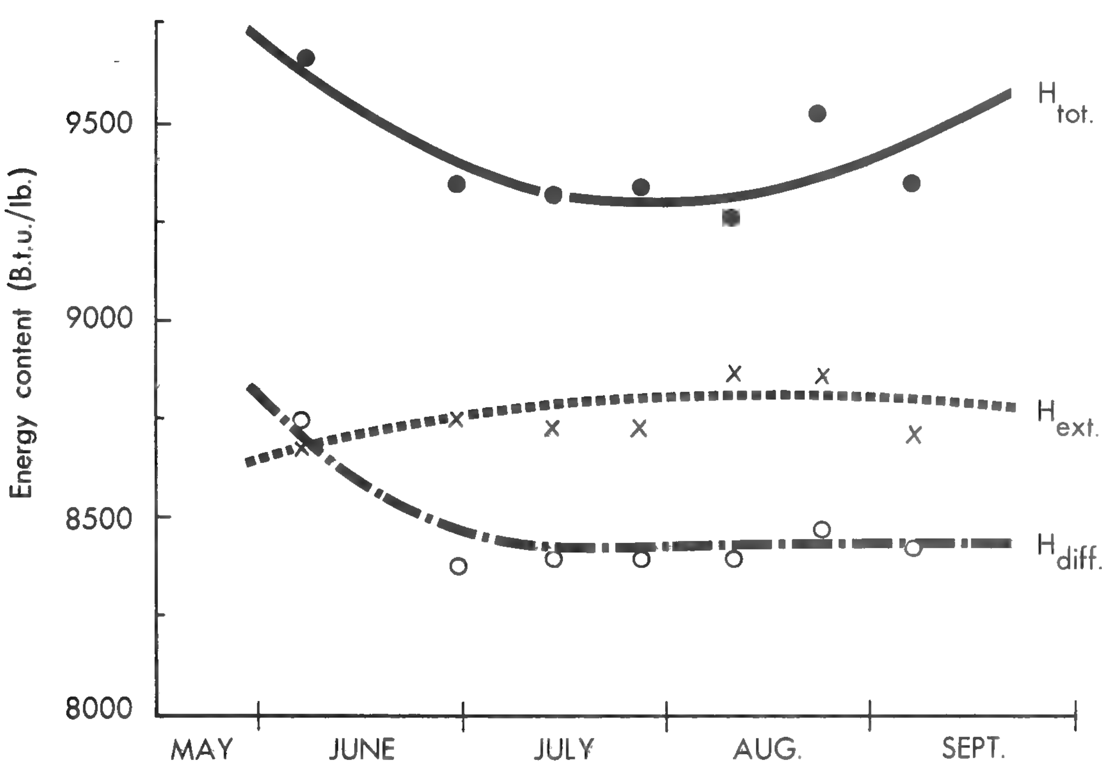

Figure 16.--The energy content of ponderosa pine needles, ether extracted needles, and H_{diff} during the 1969 fire season.

CONCLUSIONS AND DISCUSSION

The conclusions that can be made from this study are:

1. The 1- and 2-year-old needles of ponderosa pine and Douglas-fir exhibited no difference in moisture trends between 1968 and 1969. The lows for both species probably occur in winter or early spring, followed by a gradual increase during the summer. No evidence was found of a summer drying trend that could indicate a relationship between lower needle moisture and susceptibility to crown fires. The effect of new needle moisture is probably insignificant in spring because of the small mass. As this mass approaches 20-25 percent of the total foliage, the moisture content approaches that of the older needles.

2. The major change detected in ponderosa pine and Douglas-fir needles was in their ether extractive content. Generally there was a summer increase of about 100 percent for fir. The changes in pine were much smaller, although it remained relatively high throughout the fire season. The biggest gain in fir occurred in the driest year. A downward trend, corresponding to the beginning of August rains, occurred in 1968. A comparison between years is complicated by the change in sample site location.

3. The energy content of the needles of these two species was highest in the late summer. Although the energy of fir increased due to extractive increase, the energy of the extracted fuel also increased. The energy change in pine was due as much to the energy change in the extractives as it was to any increase in extractives.

These conclusions regarding crown fire potential of conifers in the northern Rocky mountains lead to interesting speculations. The extractives are probably more important than the seasonal changes in energy levels in terms of ignition and fire propagation rates. Extractives may provide a significant aspect of flame propagation within conifer crowns, and the doubling of these compounds in fir during the fire season could be important to the possibility and extent of crowning.

Another interesting possibility is that fir responds differently than pine to summer drought with regard to accumulations of extractives. Perhaps the crowning potential of pine is high for a greater portion of the year because extractives remain uniformly high, while fir is only high in crowning potential during the drier fire seasons because its extractive content varies with drought.

The seasonal energy changes of Douglas-fir and ponderosa pine foliage were only about 500 B.t.u./lb.; since this is less than 10 percent of the total energy of the needles, it would not seem too important. But when the availability of living needle energy to the combustion process is probably far less than 8,000 to 9,000 B.t.u./lb., then a gross 10-percent increase may be more meaningful. Since H_{diff} for ponderosa pine needles remained quite uniform through the season, the energy increases of fir foliage are probably of more value in the predictions of crown fires.

The importance of seasonal changes in foliar moisture to crown fires seems to need reevaluation. Actually there was little difference in moisture trends of needles between the wet 1968 season and the dry 1969 season. This difference was not tested due to the sampling site change. Mature Douglas-fir and ponderosa pine foliage increased in moisture content during each fire season. Apparently, foliar moisture content is not directly related to summer drying. Perhaps the extractives, or some portion of them, need to be considered along with moisture content in approaching the problem of crown fire susceptibility. Could it be that foliar extractives are volatilized through a steam distillation mechanism in a fire and that an increasing moisture trend enhances this combustion process within coniferous crowns? Obviously more work is needed to investigate such a possibility.

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APPENDIX

APPENDIX A

The means of moisture content for Douglas-fir needles, 1968.

Date	Code	Age 0 $\overline{X}$	Age 0 Sig.	Age 1 $\overline{X}$	Age 1 Sig.	Age 2 $\overline{X}$	Age 2 Sig.
6-10	A	95	BC	73	N[1]	70	BDEFGHIJ
6-21	B	259	ACDEFGHIJ	91	N	85	ADEFGHIJ
7-5	C	186	AB	91	N	79	DEGHIJ
7-19	D	141	B	111	N	105	ABC
7-26	E	158	B	111	N	106	ABC
8-2	F	134	B	115	N	108	ABC
8-12	G	127	B	128	N	116	ABC
8-23	H	125	B	105	N	104	ABC
9-6	I	117	B	105	N	106	ABC
11-1	J	121	B	113	N	105	ABC

[1]N = no significance from any other mean.

APPENDIX B

The means of moisture content for ponderosa pine needles, 1968

Date	Code	Age 0 $\overline{X}$	Age 0 Sig.	Age 1 $\overline{X}$	Age 1 Sig.	Age 2 $\overline{X}$	Age 2 Sig.
5-27	A	198	B	97	EGHIJKL	88	JH
6-10	B	110	ACDEFH	99	EHJL	82	EFHIJK
6-21	C	234	BIKL	94	EGHIJKL	86	HJ
7-6	D	224	BKL	108	N[1]	96	N
7-13	E	195	B	123	ABC	104	B
7-19	F	193	B	105	H	103	B
7-26	G	198	B	116	AC	102	N
8-2	H	191	B	126	ABCF	113	ABC
8-12	I	149	C	116	AC	106	B
8-23	J	155	N	120	ABC	117	ABC
9-6	K	127	CD	115	AC	105	B
11-1	L	124	CD	115	ABC	101	N

[1]N = no significance from any other mean.

APPENDIX C

The means of moisture content for Douglas-fir needles, 1969

Date	Code	Age 0 $\bar{X}$	Age 0 Sig.	Age 1 $\bar{X}$	Age 1 Sig.	Age 2 $\bar{X}$	Age 2 Sig.
6-11	A	265	BCDEFG	112	G	89	N[1]
6-30	B	180	ACDEFG	98	G	86	N
7-14	C	128	ABG	94	GE	92	N
7-28	D	125	ABG	103	G	93	N
8-11	E	137	AB	116	C	109	N
8-25	F	136	AB	108	N	99	N
9-8	G	150	ABCD	122	ABCD	96	N

[1]N = no significance from any other mean.

APPENDIX D

The means of moisture content for ponderosa pine needles, 1969

Date	Code	Age 0 $\bar{X}$	Age 0 Sig.	Age 1 $\bar{X}$	Age 1 Sig.	Age 2 $\bar{X}$	Age 2 Sig.
6-11	A	216	CDEFG	124	N[1]	81	EG
6-30	B	209	CDEFFG	95	N	83	EG
7-14	C	175	ABEFG	101	N	92	E
7-28	D	166	ADEFG	112	N	98	N
8-11	E	125	ABCD	112	N	119	ABC
8-25	F	141	ABCD	114	N	106	N
9-8	G	131	ABCD	105	N	109	AB

[1]N = no significance from any other mean.

APPENDIX E

The means of extractive content of Douglas-fir needles, 1968

Date	Code	Age 0		Age 1		Age 2	
		$\overline{X}$	Sig.	$\overline{X}$	Sig.	$\overline{X}$	Sig.
5-27	A	[1]NS		6.5	FGHJ	7.4	GH
6-10	B	NS		5.5	FGH	6.3	EFGHIJ
6-21	C	8.6	[2]N	6.0	FGH	6.8	FGHIK
7-5	D	8.1	N	6.2	FGH	6.5	EFGHIK
7-19	E	7.6	N	7.4	N	7.7	BD
7-26	F	9.1	J	8.1	ABCD	8.5	BCD
8-2	G	9.5	J	8.0	ABCDJ	8.7	ABCDJ
8-12	H	8.5	N	8.0	ABCDJ	8.7	ABCDJ
8-23	I	7.7	N	7.7	N	8.1	BCD
9-6	J	6.9	GF	6.8	FGH	7.4	BGH
11-1	K	8.2	N	7.9	N	8.3	BCD

[1]NS = not sampled.
[2]N = No significance from any other mean.

APPENDIX F

The means of extractive content of ponderosa pine, 1968

Date	Code	Age 0		Age 1		Age 2	
		$\overline{X}$	Sig.	$\overline{X}$	Sig.	$\overline{X}$	Sig.
5-27	A	[1]NS		10.6	DEFGJK	11.6	BCDEFGHIJKL
6-10	B	NS		9.1	[2]N	9.1	A
6-21	C	NS		9.8	N	9.2	A
7-6	D	4.7	L	9.1	A	8.2	A
7-13	E	5.4	L	8.0	A	8.8	A
7-19	F	4.8	L	7.5	A	7.6	A
7-26	G	4.9	L	7.9	A	7.9	A
8-2	H	5.1	L	8.7	N	9.0	A
8-12	I	5.3	L	8.8	N	9.0	A
8-23	J	5.4	L	7.5	A	7.9	A
9-6	K	5.4	L	7.5	A	8.0	A
11-1	L	7.9	DEFGHIJK	9.2	N	9.1	A

[1]NS = not sampled.
[2]No significance from any other mean.

APPENDIX G

The means of extractive content of Douglas-fir needles, 1969

Date	Code	Age 0 $\overline{X}$	Age 0 Sig.	Age 1 $\overline{X}$	Age 1 Sig.	Age 2 $\overline{X}$	Age 2 Sig.
6-11	A	10.4	BCDEFG	5.9	BC	6.1	BC
6-30	B	4.7	ADEFG	4.8	DEFG	4.9	DEFG
7-14	C	4.6	DEFG	4.6	ADEFG	4.7	ADEFG
7-28	D	7.6	BC	7.2	ABC	6.9	ABC
8-11	E	7.8	BC	6.6	BC	7.4	ABC
8-25	F	8.9	BC	7.8	ABC	7.9	ABCD
9-8	G	8.0	BC	7.7	ABC	7.3	ABC

APPENDIX H

The means of extractive content of ponderosa pine needles, 1969

Date	Code	Age 0 $\overline{X}$	Age 0 Sig.	Age 1 $\overline{X}$	Age 1 Sig.	Age 2 $\overline{X}$	Age 2 Sig.
6-11	A	4.9	BFG	8.4	[1]N	7.3	N
6-30	B	3.7	DEFG	7.4	N	7.2	N
7-14	C	4.2	FG	8.3	N	8.0	N
7-28	D	4.8	B	7.6	N	7.8	N
8-11	E	5.1	B	8.7	N	8.0	N
8-25	F	6.3	ABCDE	8.5	N	8.5	N
9-8	G	6.5	ABDCE	8.5	N	8.3	N

[1]N = No significance from any other mean.

AFLC/HAFB, Ogden

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field Research Work Units are maintained in:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)